PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-027994
(43)Date of publication of application : 30.01.2001

(51)Int.Cl. G06F 17/10
G06F 17/50

(21)Application number : 11-200860
(22)Date of filing : 14.07.1999

(71)Applicant : YAGAWA MOTOKI
TOYO COMMUN EQUIP CO LTD

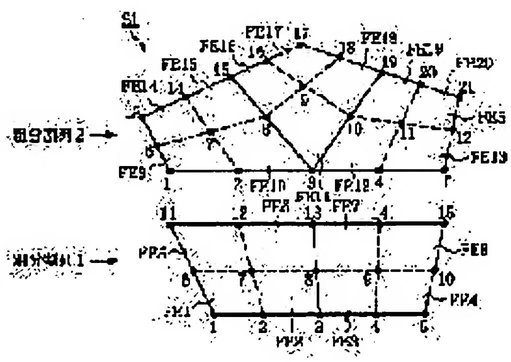
(72)Inventor : YAGAWA MOTOKI
AOYAMA YUJI

(54) METHOD AND DEVICE FOR GENERATING NUMERIC DATA FOR CALCULATION FROM ANALYTIC MODEL BY FINITE ELEMENT METHOD

(57)Abstract:

PROBLEM TO BE SOLVED: To decrease the calculation quantity and memory capacity needed for a structure analysis by a finite element method, etc., even when the shape of a structure is complicated and elements and nodes are large in number.

SOLUTION: An analytic model for the structure is roughly divided into rough divisional elements first and rough divisional elements which are arranged in one direction is set as one array to set the analytic model for the structure as multiple arrays 1 and 2; and the rough divisional elements are further divided into fine divisional elements FE1 to FE20, node numbers 1 to 15 and 1 to 21 are set to each of nodes of the fine divisional elements according to the arrays, and multiple arrays are integrated to obtain the whole analytic model. Then the node numbers at each of the nodes of the fine divisional elements are charged into node numbers of the whole analytic model.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

CLAIMS

[Claim(s)]
[Claim 1] A joint number is given to the joint for every element while dividing the analytic model of the structure into two or more elements. It is the data generation method which generates calculating numeric data from the analytic model by the finite element method which analyzes the behavior of the whole structure by adding the numeric value showing the physical quantity in each joint number. The 1st step where the processing which divides said analytic model into an element is divided coarsely, and uses said analytic model as a rough division element, The data generation method which generates calculating numeric data from the analytic model by the finite element method characterized by carrying out by dividing into step [which re-divides said rough division element further, and is used as a fragmentation element / 2nd] two steps.
[Claim 2] The data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 1 characterized by constituting said analytic model by said two or more rough division element trains by setting up the rough division element train of one train in the 1st-step division processing of said analytic model about said two or more rough division elements located in a line with the one direction.
[Claim 3] The data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 2 characterized by setting up the joint number to said each joint as a joint number for rough division trains along the direction where said rough division element is located in a line for said two or more rough division element trains of every.
[Claim 4] The data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 3 characterized by resetting it as the joint number of the order which unified the joint number of said whole analytic model based on said contact numerical order for rough division trains while unifying each train of said ****** element train and returning to said whole analytic-model configuration.
[Claim 5] The input unit which can input various alphabetic characters and numeric values, such as data and a program, The storage which memorizes the program and data which analyze the behavior of the structure with this analytic model while memorizing the analytic model by the finite element method of the structure at least, Count equipment equipped with the processor which generates calculating numeric data by count from said analytic model with the application of said program and said data, The count result of said count equipment A display unit, an airline printer, external storage, It is data generation equipment which generates calculating numeric data from the analytic model by the finite element method equipped with the output unit which can be outputted to a communication device etc. or for said program The contents for performing the data generation method which generates calculating numeric data from the analytic model by the finite element method indicated by any 1 term of claims 1-3 are indicated. With said count equipment Data generation equipment which generates calculating numeric data from the analytic model by the finite element method characterized by generating calculating numeric data from said analytic model with said data generation method.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the data generation method which generates calculating numeric data from the analytic model used for structural analysis by the finite element method.
[0002]
[Description of the Prior Art] Setting up the analytic model of the structure which analyzes, and the analytic model generating calculating numeric data, and performing structural analysis from the former, in case structural analysis etc. is performed with the finite element method is known. Moreover, in analyzing movement, heat conduction, etc. of the structure using the finite element method generally, according to the following procedures, it performs processing etc. roughly.
(1) Set up the analytic model of the structure and divide an analytic model into a finite element.
(2) Assign the serial number to each divided element and each of each joint on each element.
(3) Generate the numeric data containing the coordinate of each joint, the number of each joint on each element, etc.
It is as follows when the above-mentioned procedure is explained in more detail. The analytic model by the finite element method is set up in how the structure is analyzed first. the analytic model -- fineness required for analysis -- dividing -- an element (if it is for example, in a two-dimensional model -- the element of a triangle or a square {= quadrilateral} --) If it is in a three-dimension model, elements, such as a tetrahedron or six face pieces, are set up, a joint number is assigned to every [of the element] angle (joint), the element matrix which contained the component of a surrounding joint number for every joint number is generated, and analysis is calculated by generating a whole matrix by unifying the element matrix. By the way, when dividing an analytic model, even the element of fineness required for analysis divided the analytic model at a time conventionally, and the joint number was assigned in order of arbitration at each joint.
[0003] However, in assigning a joint number in order of arbitration, since the difference of the greatest joint number in one element (for example, quadrilateral element) and the minimum joint number becomes large and the half-band width mentioned later becomes large, it has the problem that the time amount and cost which count of analysis takes become large. For example, even if it is the analytic model of the same number of joints which performed element division similarly, the computational complexity and the amount of memory needed in the finite element method enforced after that change with the differences in an approach to assign a joint number a lot. This is because the locations within the matrix of zero element in the matrix generated depending on how to assign a joint number and un-0 element differ. The amount of memory which the matrix of un-0 element generally generated by the finite element method is a band matrix which contains the component of predetermined width of face focusing on the diagonal element within a matrix, and the computational complexity of a matrix and count take with the half-band width of the band matrix is determined. The technique of the Cuthill-Mckee method is known as the technique of changing the joint number of a fragmentation element, in order to solve the problem that computation time increases depending on how to assign this joint number. The Cuthill-Mckee method Reference "E. H.Cuthill and J.M.Mckee and Reducing the bandwidth of sparse symmetric matrices.Proc.24th National As indicated by Conference ACM,

Bandon Systems Press, HJ, 1969, and 157-172" By changing the joint number of each element with the application of a predetermined algorithm, it is the approach of lessening time amount which gathers the count effectiveness of analysis and count takes. However, the Cuthill-Mckee method may have the huge computational complexity of the algorithm which rearranges a joint number, since the processing time is the need mostly, when there are few numbers of elements and joints, it may be effective as the technique of solving the problem of lessening time amount which count of analysis takes, but when there are many numbers of elements and joints, it is not suitable for the problem solving. Here, it explains using an actual example that the computational complexity of a matrix changes with how to assign a joint number.

[0004] Drawing 7 is drawing showing the matrix generally generated by the finite element method. The diagonal line turned to the lower right angle from the upper left hand corner of the matrix of drawing 7 shows the diagonal element in a matrix, and the band matrix of un-0 element is formed in the both sides of the diagonal element. The outside of the band matrix in a matrix is the triangular matrix of zero element. In this matrix, the width of face to the element component of the outermost part of a band matrix turns into half-band width from a diagonal element. Drawing 8 is drawing showing the example of the matrix of drawing 7 . Drawing 8 (a) is drawing showing the case where the analytic model of a rectangular parallelepiped configuration is divided into six. The analytic model in drawing 8 (a) is trichotomized by the longitudinal direction, and is carried out 6 ****s while 2 ****s is carried out in the vertical direction. As for each divided element of an analytic model, each element of e4, e5, and e6 is located in a line by each element of e1, e2, and e3 towards the upper left to a list and the right towards the right from the lower left. The joint numbers in which the joint number of drawing 8 (a) is located the lower side of elements e1-e3 are 1, 2, 3, and 4 sequentially from the left. The joint numbers located the boundary side of elements e1-e3 and elements e4-e6 are 5, 6, 7, and 8 sequentially from the left, and the joint numbers located in the surface of elements e4-e6 are 9, 10, 11, and 12 sequentially from the left. Drawing 8 (b) is drawing showing the element matrix in each joint number of the element e1 of drawing 8 (a). By assigning a joint number like drawing 8 (a), 1, 2, 5, and 6 are assigned in order to each of the row and column in the element matrix of drawing 8 (b). All the elements in the element matrix of this drawing 8 (b) are usually un-0 elements. Drawing 8 (c) is drawing which generated the element matrix to the element e2 according to the element matrix about the element e1 shown in drawing 8 (b) - an element e6, and generated the whole matrix which unified each of that element matrix. For example, about the line of the joint number 1, as shown in drawing 8 (b), the element of an intersection with the train of the joint numbers 1, 2, 5, and 6 turns into un-0 element. the same -- an intersection with the train of the joint numbers 1, 2, 5, and 6 same about the line of the joint number 2 as the joint number 1 -- in addition, although an intersection element with the train of the joint numbers 2, 3, 6, and 7 which are joint numbers of an element e2 turns into un-0 element Since the joint numbers 2 and 6 are common to an element e1 and an element e2, the element of an intersection with the train of the joint numbers 1, 2, 3, 5, 6, and 7 turns into un-0 element. Hereafter, un-0 element is similarly arranged based on said each element matrix about the line of the joint numbers 3-12, and a band matrix is formed. Moreover, if width of face to the element of the end of a band matrix from the element of a diagonal element is made into half-band width, it will be set to 6 in drawing 8 (c). Moreover, the half-band width in this case is the maximum of the joint number for every element, and the inner maximum which extracted the difference of the minimum value about all elements. The computational complexity in the analysis of the structure using the finite element method changes by whether this half-band width is wide or narrow. Although the half-band width in the case of drawing 8 (c) is 6, if this is set to 7, computational complexity will increase, and computational complexity will become less if set to 5. In order to reduce this half-band width, as described above, a replacement of a joint number is performed.

[0005] Drawing 9 is drawing having shown the example of being able to reduce half-band width by changing the joint number of the analytic model of drawing 8 . Drawing 9 (a) shows the case where the analytic model of a rectangular parallelepiped configuration is divided into six like drawing 8 (a), and the analytic model is trichotomized by the longitudinal direction and carried out 6 ****s while 2 ****s is carried out in the vertical direction. As for each divided element of an analytic model, each element of e14, e15, and e16 is located in a line by each element of e11, e12, and e13 towards the upper left to a list and the right towards the right from the lower left. The joint numbers to which the joint number of drawing 9 (a) is located in the left part of

elements e11 and e14 are 1, 2, and 3 sequentially from the bottom. The joint numbers located the boundary side of elements e11 and e14 and elements e12 and e15 are 4, 5, and 6 sequentially from the bottom. The joint numbers located the boundary side of elements e12 and e15 and elements e13 and e16 are 7, 8, and 9 sequentially from the bottom, and the joint numbers located in the right-hand side of elements e13 and e16 are 10, 11, and 12 sequentially from the bottom. Drawing 9 (b) is drawing showing the element matrix in each joint number of the element e11 of drawing 9 (a). By assigning a joint number like drawing 9 (a), 1, 2, 4, and 5 are assigned in order to each of the row and column in the element matrix of drawing 9 (b). All the elements in the element matrix of this drawing 9 (b) are usually un-0 elements. Drawing 9 (c) is drawing which generated the element matrix to the element e12 according to the element matrix about the element e11 shown in drawing 9 (b) - an element e16, and generated the whole matrix which unified each of that element matrix. For example, about the line of the joint number 1, as shown in drawing 9 (b), the element of an intersection with the train of the joint numbers 1, 2, 4, and 5 turns into un-0 element. the same -- an intersection with the train of the joint numbers 1, 2, 4, and 5 same about the line of the joint number 2 as the joint number 1 -- in addition, although an intersection element with the train of the joint numbers 2, 3, 5, and 6 which are joint numbers of an element e14 turns into un-0 element Since the joint numbers 2 and 5 are common to an element e11 and an element e14, the element of an intersection with the train of the joint numbers 1, 2, 3, 4, 5, and 6 turns into un-0 element. Hereafter, un-0 element is similarly arranged based on said each element matrix about the line of the joint numbers 3-12, and a band matrix is formed. Moreover, if width of face to the element of the end of a band matrix from the element of a diagonal element is made into half-band width, it will be set to 5 in drawing 9 (c). Since the half-band width in the case of drawing 9 (c) is 5, it will be narrower than the half-band width 6 in the case of drawing 8 (c). Therefore, it means that the computational complexity of a whole matrix had become less by having changed the joint number like [in the case of drawing 9 (c)] from the case of drawing 8 (c).

[0006]

[Problem(s) to be Solved by the Invention] When the configuration of an analytic model becomes complicated and the number of elements and the number of joints increase, it becomes impossible by the way, for a replacement of a joint number to change a joint number easily as mentioned above simply [the configuration of an analytic model] like [in the case of drawing 8 or drawing 9], although it can carry out easily when there are few numbers of elements and joints. namely, -- the case of the structure (namely, analytic model) of a complicated configuration or a big configuration -- easy -- a replacement of a joint number -- it cannot do -- said Cuthill-Mckee carried out -- since the computational complexity which a replacement of a joint number takes increases when law also has many elements, neither computational complexity nor the amount of memory to need can be reduced. analysis of the structure according to the finite element method when a calculating-machine side cannot respond to the increment in computational complexity or the amount of memory, after dividing an analytic model coarsely -- not carrying out -- it will not obtain but the precision fall of count will be caused. This invention is made in order to solve the problem of the **** former mentioned above, and even if it is a case with many [intricately / the number of elements and the number of joints] configurations of the structure, it aims at offering the data generation method which generates the calculating numeric data which can reduce the computational complexity and the amount of memory which are needed for structural analyses, such as the finite element method, from the analytic model by the finite element method.

[0007]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, the data generation method which generates calculating numeric data from the analytic model by the finite element method of this invention of claim 1 A joint number is given to the joint for every element while dividing the analytic model of the structure into two or more elements. It is the data generation method which generates calculating numeric data from the analytic model by the finite element method which analyzes the behavior of the whole structure by adding the numeric value showing the physical quantity in each joint number. It is characterized by performing processing which divides said analytic model into an element by dividing into two steps (the 1st step which divides said analytic model coarsely and is used as a rough division element, and the 2nd step which re-divides said rough division element further, and is used as a fragmentation element). This invention of

claim 2 is characterized by constituting said analytic model by said two or more rough division element trains by setting up the rough division element train of one train about said two or more rough division elements located in a line with the one direction in the 1st-step division processing of said analytic model in the data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 1. This invention of claim 3 is characterized by setting up the joint number to said each joint as a joint number for rough division trains along the direction where said rough division element is located in a line for said two or more rough division element trains of every in the data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 2.

[0008] In the data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 3, this invention of claim 4 is characterized by resetting it as the joint number of the order which unified the joint number of said whole analytic model based on said contact numerical order for rough division trains while it unifies each train of said ****** element train and returns it to said whole analytic-model configuration. The data generation equipment which generates calculating numeric data from the analytic model by the finite element method of this invention of claim 5 The input unit which can input various alphabetic characters and numeric values, such as data and a program, The storage which memorizes the program and data which analyze the behavior of the structure with this analytic model while memorizing the analytic model by the finite element method of the structure at least, Count equipment equipped with the processor which generates calculating numeric data by count from said analytic model with the application of said program and said data, The count result of said count equipment A display unit, an airline printer, external storage, It is data generation equipment which generates calculating numeric data from the analytic model by the finite element method equipped with the output unit which can be outputted to a communication device etc. or for said program The contents for performing the data generation method which generates calculating numeric data from the analytic model by the finite element method indicated by any 1 term of claims 1-3 are indicated. With said count equipment It is characterized by generating calculating numeric data from said analytic model with said data generation method. As mentioned above, by setting up that to which the analytic model of the structure was coarsely divided into the rough division element at first, next two or more the rough division elements were located in a line with the one direction with one train Constitute the analytic model of the structure from two or more trains, and said rough division element is further re-divided into a fragmentation element. While setting a joint number as each joint of each fragmentation element along with the list of said train, unifying said two or more trains finally and considering as the whole analytic model By changing for the joint number which lets the whole analytic model pass about the joint number in each joint of each fragmentation element, it makes it possible to reduce the computational complexity and the amount of memory which are needed for structural analyses, such as the finite element method.

[0009]

[Embodiment of the Invention] Hereafter, it explains based on the operation gestalt illustrating this invention. Drawing 1 is drawing showing an example of the analytic model of the structure. As shown in drawing 1 , this analytic model was made into the two-dimensional analytic model S1 which has a five-cornered configuration. This analytic model S1 is explained below about the case where it divides into the element of a four-side form. As shown in drawing 2 , an analytic model S1 is first divided into the rough division elements RE1-RE5 of a four-side form coarsely. Drawing 3 is drawing showing the case where a rough division train is set up according to the list of the one direction of the rough division element of drawing 2 . The rough division element RE1 and the rough division element RE2 are located in a line with the one direction (the one-dimension-array direction) of right and left among drawing, and set up the rough division train 1 with the rough division element RE1 and the rough division element RE2. Similarly, the rough division element RE3 - the rough division element RE5 are located in a line with the one direction (the one-dimension-array direction) of right and left among drawing, and set up the rough division train 2 with the rough division element RE3 - the rough division element RE5. Drawing 4 is drawing showing the case where each ****** element of the rough division train 1 of drawing 3 and the rough division train 2 is re-divided into a fragmentation element required for

analysis. The rough division train 1 of drawing 4 is carried out 2 ****s further up and down, and 2 ****s of each are made right and left also for the rough division element RE1 and the rough division element RE2. Namely, as for the rough division element RE1 and the rough division element RE2, each element with which each rough division element was further quadrisected, and was divided turns into a fragmentation element. The rough division train 1 sets to FE1, FE2, FE3, and FE4 from the left the fragmentation element of the train of the bottom carried out 2 ****s up and down at order. Moreover, the fragmentation element of the train of the top is set to FE5, FE6, FE7, and FE8 from the left at order. A joint number is set up with 1, 2, 3, 4, and 5 sequentially from the left about the joint number of the fragmentation element FE1, FE2, FE3, and FE4 bottom. Moreover, it sets up with 6, 7, 8, 9, and 10 sequentially from the left about the joint number of the fragmentation element FE1, FE2, FE3, and FE4 top and the fragmentation element FE5, FE6, FE7, and FE8 bottom. Furthermore, it sets up with 11, 12, 13, 14, and 15 sequentially from the left about the joint number of the fragmentation element FE5, FE6, FE7, and FE8 top.
[0010] Since it cannot divide into two up and down simply, the rough division train 2 of drawing 4 is first divided into two up and down about the rough division elements RE3 and RE4. Furthermore, it divides into two up and down about the rough division elements RE4 and RE5. Then, the rough division element RE4 will be quadrisected. About the rough division elements RE3 and RE5, it divides into two like the rough division elements RE1 and RE2 at right and left. Thus, by dividing, all the rough division elements RE3-RE of the rough division train 2 are quadrisected, and each divided element turns into a fragmentation element. The rough division train 2 sets to FE9, FE10, FE11, FE12, and FE13 from the left the fragmentation element of the train of the bottom carried out 2 ****s up and down at order. Moreover, the fragmentation element of the train of the top is set to FE14, FE15, FE16, FE17, FE18, FE19, and FE20 from the left at order. A joint number is set up with 1, 2, 3, 4, and 5 sequentially from the left about the joint number of the fragmentation element FE9, FE10, FE11, FE12, and FE13 bottom. Moreover, it sets up with 6, 7, 8, 9, 10, 11, and 12 sequentially from the left about the joint number of the fragmentation element FE9, FE10, FE11, FE12, and FE13 top and the fragmentation element FE14, FE15, FE16, FE17, FE18, FE19, and FE20 bottom. Furthermore, it sets up with 13, 14, 15, 16, 17, 18, 19, 20, and 21 sequentially from the left about the joint number of the fragmentation element FE14, FE15, FE16, FE17, FE18, FE19, and FE20 top. Drawing 5 is drawing showing what (it changed) the rough division train of drawing 4 is unified and the joint number reset up for to the whole analytic model. In drawing 5 , the rough division train 1 and the rough division train 2 are unified, and constitute the analytic model S1. Although the configuration of the fragmentation elements FE1-FE20 is the same as the configuration of drawing 4 except that the rough division train 1 and the rough division train 2 are joined, the joint number in the rough division train 2 of drawing 4 is reset up. About the joint numbers 1-5 of the rough division train 2 of drawing 4 , since it joins to the joint numbers 11-15 of the rough division train 1, and 1 to 1 by integration with the rough division train 1, the joint numbers 1-5 disappear taking advantage of the joint numbers 11-15. About the joint numbers 6-12 of the rough division train 2 of drawing 4 , since it becomes the next joint number of the joint numbers 11-15 of the rough division train 1 by integration with the rough division train 1, it resets the joint numbers 6-12 with the joint numbers 16-22. About the joint numbers 13-21 of the rough division train 2 of drawing 4 , since it becomes the next joint number of the joint numbers 16-22 of the rough division train 2 by integration with the rough division train 1, it resets the joint numbers 13-21 with the joint numbers 23-31.
[0011] Drawing 6 is the block diagram showing 1 operation gestalt of the data generation equipment which generates calculating numeric data from the analytic model by the finite element method of this invention. In the data generation equipment 1 which generates calculating numeric data from the analytic model by the finite element method of this invention, it is constituted by the output unit 5 which outputs the count result by the storage 4 and the count equipment 3 which memorizes programs, the various set points or various data etc. which generate calculating numeric data, such as a data generation method, etc. from the analytic model by the input devices 2, such as a keyboard and a digitizer, the count equipment 3 which consists of two or more processors, and the finite element method. First, the operator of count equipment 1 inputs beforehand programs, such as a data generation method which generates calculating numeric data from the analytic model by the finite element method, with an input unit 2, and stores them in storage 4. Next, the operator of count equipment 1 inputs the various set points, data, etc. with an input unit 2. Count equipment 3 performs count

based on the various set points and data which read the program of the data generation method which generates calculating numeric data from the analytic model by the finite element method from the store 4 with the inputted various set points, and were inputted. A count result is outputted from the output unit 5 of count equipment 1. It is recognized by the operator with a display unit, an airline printer, etc., external storage memorizes, or processing of being outputted to a network by the communication device is carried out to the count result outputted from count equipment 1. As mentioned above, since data can be generated using the data generation method which generates calculating numeric data from the analytic model by the finite element method of this invention in case the structure is analyzed with count equipment, computational complexity and the amount of memory required for count are reducible. In addition, although this operation gestalt showed the case of the train to which the rough division element was located in a line with right and left (longitudinal direction in drawing) about the rough division train, it is not necessary to restrict this invention to this, and when it is the train to which the rough division train was located in a line with the upper and lower sides (lengthwise direction in drawing) that what is necessary is just to have stood in a line on the single dimension, or also when it is the train aslant located in a line, it can apply, and the array does not need to be a straight line strictly.

[0012]

[Effect of the Invention] By this invention, as mentioned above by setting up that to which the analytic model of the structure was coarsely divided into the rough division element at first, next two or more the rough division elements were located in a line with the one direction with one train While setting the analytic model of the structure as two or more trains, re-dividing said rough division element into a fragmentation element further, setting a joint number as each joint of each fragmentation element according to the list of said train, unifying said two or more trains finally and considering as the whole analytic model The difference of the joint number in each element can be made comparatively small, performing fine element division which is needed for structural analyses, such as the finite element method, since it changes for the joint number which lets the whole analytic model pass about the joint number in each joint of each fragmentation element. Therefore, the computational complexity and the amount of memory requirements at the time of count of the analysis of the analytic model using the finite element method can be reduced.

[Translation done.]

TECHNICAL FIELD

[Field of the Invention] This invention relates to the data generation method which generates calculating numeric data from the analytic model used for structural analysis by the finite element method.

[Translation done.]

* NOTICES *

PRIOR ART

[Description of the Prior Art] Setting up the analytic model of the structure which analyzes, and the analytic model generating calculating numeric data, and performing structural analysis from the former, in case structural analysis etc. is performed with the finite element method is known. Moreover, in analyzing movement, heat conduction, etc. of the structure using the finite element method generally, according to the following procedures, it performs processing etc. roughly.
(1) Set up the analytic model of the structure and divide an analytic model into a finite element.
(2) Assign the serial number to each divided element and each of each joint on each element.
(3) Generate the numeric data containing the coordinate of each joint, the number of each joint on each element, etc.
It is as follows when the above-mentioned procedure is explained in more detail. The analytic model by the finite element method is set up in how the structure is analyzed first. the analytic model -- fineness required for analysis -- dividing -- an element (if it is for example, in a two-dimensional model -- the element of a triangle or a square {= quadrilateral} --) If it is in a three-dimension model, elements, such as a tetrahedron or six face pieces, are set up, a joint number is assigned to every [of the element] angle (joint), the element matrix which contained the component of a surrounding joint number for every joint number is generated, and analysis is calculated by generating a whole matrix by unifying the element matrix. By the way, when dividing an analytic model, even the element of fineness required for analysis divided the analytic model at a time conventionally, and the joint number was assigned in order of arbitration at each joint.
[0003] However, in assigning a joint number in order of arbitration, since the difference of the greatest joint number in one element (for example, quadrilateral element) and the minimum joint number becomes large and the half-band width mentioned later becomes large, it has the problem that the time amount and cost which count of analysis takes become large. For example, even if it is the analytic model of the same number of joints which performed element division similarly, the computational complexity and the amount of memory needed in the finite element method enforced after that change with the differences in an approach to assign a joint number a lot. This is because the locations within the matrix of zero element in the matrix generated depending on how to assign a joint number and un-0 element differ. The amount of memory which the matrix of un-0 element generally generated by the finite element method is a band matrix which contains the component of predetermined width of face focusing on the diagonal element within a matrix, and the computational complexity of a matrix and count take with the half-band width of the band matrix is determined. The technique of the Cuthill-Mckee method is known as the technique of changing the joint number of a fragmentation element, in order to solve the problem that computation time increases depending on how to assign this joint number. The Cuthill-Mckee method Reference "E. H.Cuthill and J.M.Mckee and Reducing the bandwidth of sparse symmetric matrices.Proc.24th National As indicated by Conference ACM, Bandon Systems Press, HJ, 1969, and 157-172" By changing the joint number of each element with the application of a predetermined algorithm, it is the approach of lessening time amount which gathers the count effectiveness of analysis and count takes. However, the Cuthill-Mckee method may have the huge computational complexity of the algorithm which rearranges a joint number, since the processing time is the need mostly, when there are few numbers of elements and joints, it may be effective as the technique of

solving the problem of lessening time amount which count of analysis takes, but when there are many numbers of elements and joints, it is not suitable for the problem solving. Here, it explains using an actual example that the computational complexity of a matrix changes with how to assign a joint number.

[0004] Drawing 7 is drawing showing the matrix generally generated by the finite element method. The diagonal line turned to the lower right angle from the upper left hand corner of the matrix of drawing 7 shows the diagonal element in a matrix, and the band matrix of un-0 element is formed in the both sides of the diagonal element. The outside of the band matrix in a matrix is the triangular matrix of zero element. In this matrix, the width of face to the element component of the outermost part of a band matrix turns into half-band width from a diagonal element. Drawing 8 is drawing showing the example of the matrix of drawing 7 . Drawing 8 (a) is drawing showing the case where the analytic model of a rectangular parallelepiped configuration is divided into six. The analytic model in drawing 8 (a) is trichotomized by the longitudinal direction, and is carried out 6 ****s while 2 ****s is carried out in the vertical direction. As for each divided element of an analytic model, each element of e4, e5, and e6 is located in a line by each element of e1, e2, and e3 towards the upper left to a list and the right towards the right from the lower left. The joint numbers in which the joint number of drawing 8 (a) is located the lower side of elements e1-e3 are 1, 2, 3, and 4 sequentially from the left. The joint numbers located the boundary side of elements e1-e3 and elements e4-e6 are 5, 6, 7, and 8 sequentially from the left, and the joint numbers located in the surface of elements e4-e6 are 9, 10, 11, and 12 sequentially from the left. Drawing 8 (b) is drawing showing the element matrix in each joint number of the element e1 of drawing 8 (a). By assigning a joint number like drawing 8 (a), 1, 2, 5, and 6 are assigned in order to each of the row and column in the element matrix of drawing 8 (b). All the elements in the element matrix of this drawing 8 (b) are usually un-0 elements. Drawing 8 (c) is drawing which generated the element matrix to the element e2 according to the element matrix about the element e1 shown in drawing 8 (b) - an element e6, and generated the whole matrix which unified each of that element matrix. For example, about the line of the joint number 1, as shown in drawing 8 (b), the element of an intersection with the train of the joint numbers 1, 2, 5, and 6 turns into un-0 element. the same -- an intersection with the train of the joint numbers 1, 2, 5, and 6 same about the line of the joint number 2 as the joint number 1 -- in addition, although an intersection element with the train of the joint numbers 2, 3, 6, and 7 which are joint numbers of an element e2 turns into un-0 element Since the joint numbers 2 and 6 are common to an element e1 and an element e2, the element of an intersection with the train of the joint numbers 1, 2, 3, 5, 6, and 7 turns into un-0 element. Hereafter, un-0 element is similarly arranged based on said each element matrix about the line of the joint numbers 3-12, and a band matrix is formed. Moreover, if width of face to the element of the end of a band matrix from the element of a diagonal element is made into half-band width, it will be set to 6 in drawing 8 (c). Moreover, the half-band width in this case is the maximum of the joint number for every element, and the inner maximum which extracted the difference of the minimum value about all elements. The computational complexity in the analysis of the structure using the finite element method changes by whether this half-band width is wide or narrow. Although the half-band width in the case of drawing 8 (c) is 6, if this is set to 7, computational complexity will increase, and computational complexity will become less if set to 5. In order to reduce this half-band width, as described above, a replacement of a joint number is performed.

[0005] Drawing 9 is drawing having shown the example of being able to reduce half-band width by changing the joint number of the analytic model of drawing 8 . Drawing 9 (a) shows the case where the analytic model of a rectangular parallelepiped configuration is divided into six like drawing 8 (a), and the analytic model is trichotomized by the longitudinal direction and carried out 6 ****s while 2 ****s is carried out in the vertical direction. As for each divided element of an analytic model, each element of e14, e15, and e16 is located in a line by each element of e11, e12, and e13 towards the upper left to a list and the right towards the right from the lower left. The joint numbers to which the joint number of drawing 9 (a) is located in the left part of elements e11 and e14 are 1, 2, and 3 sequentially from the bottom. The joint numbers located the boundary side of elements e11 and e14 and elements e12 and e15 are 4, 5, and 6 sequentially from the bottom. The joint numbers located the boundary side of elements e12 and e15 and elements e13 and e16 are 7, 8, and 9 sequentially from the bottom, and the joint numbers located in the right-hand side of elements e13 and e16 are 10, 11, and 12 sequentially from the bottom. Drawing 9 (b) is drawing showing the element matrix in each

joint number of the element e11 of drawing 9 (a). By assigning a joint number like drawing 9 (a), 1, 2, 4, and 5 are assigned in order to each of the row and column in the element matrix of drawing 9 (b). All the elements in the element matrix of this drawing 9 (b) are usually un-0 elements. Drawing 9 (c) is drawing which generated the element matrix to the element e12 according to the element matrix about the element e11 shown in drawing 9 (b) - an element e16, and generated the whole matrix which unified each of that element matrix. For example, about the line of the joint number 1, as shown in drawing 9 (b), the element of an intersection with the train of the joint numbers 1, 2, 4, and 5 turns into un-0 element. the same -- an intersection with the train of the joint numbers 1, 2, 4, and 5 same about the line of the joint number 2 as the joint number 1 -- in addition, although an intersection element with the train of the joint numbers 2, 3, 5, and 6 which are joint numbers of an element e14 turns into un-0 element Since the joint numbers 2 and 5 are common to an element e11 and an element e14, the element of an intersection with the train of the joint numbers 1, 2, 3, 4, 5, and 6 turns into un-0 element. Hereafter, un-0 element is similarly arranged based on said each element matrix about the line of the joint numbers 3-12, and a band matrix is formed. Moreover, if width of face to the element of the end of a band matrix from the element of a diagonal element is made into half-band width, it will be set to 5 in drawing 9 (c). Since the half-band width in the case of drawing 9 (c) is 5, it will be narrower than the half-band width 6 in the case of drawing 8 (c). Therefore, it means that the computational complexity of a whole matrix had become less by having changed the joint number like [in the case of drawing 9 (c)] from the case of drawing 8 (c).

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] It is setting up that to which the analytic model of the structure was coarsely divided into the rough division element at first, next two or more the rough division elements' were located in a line with the one direction with one train by this invention as mentioned above, While setting the analytic model of the structure as two or more trains, re-dividing said rough division element into a fragmentation element further, setting a joint number as each joint of each fragmentation element according to the list of said train, unifying said two or more trains finally and considering as the whole analytic model The difference of the joint number in each element can be made comparatively small, performing fine element division which is needed for structural analyses, such as the finite element method, since it changes for the joint number which lets the whole analytic model pass about the joint number in each joint of each fragmentation element. Therefore, the computational complexity and the amount of memory requirements at the time of count of the analysis of the analytic model using the finite element method can be reduced.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] When the configuration of an analytic model becomes complicated and the number of elements and the number of joints increase, it becomes impossible by the way, for a replacement of a joint number to change a joint number easily as mentioned above simply [the configuration of an analytic model] like [in the case of drawing 8 or drawing 9], although it can carry out easily when there are few numbers of elements and joints. namely, -- the case of the structure (namely, analytic model) of a complicated configuration or a big configuration -- easy -- a replacement of a joint number -- it cannot do -- said Cuthill-Mckee carried out -- since the computational complexity which a replacement of a joint number takes increases when law also has many elements, neither computational complexity nor the amount of memory to need can be reduced. analysis of the structure according to the finite element method when a calculating-machine side cannot respond to the increment in computational complexity or the amount of memory, after dividing an analytic model coarsely -- not carrying out -- it will not obtain but the precision fall of count will be caused. This invention is made in order to solve the problem of the **** former mentioned above, and even if it is a case with many [intricately / the number of elements and the number of joints] configurations of the structure, it aims at offering the data generation method which generates the calculating numeric data which can reduce the computational complexity and the amount of memory which are needed for structural analyses, such as the finite element method, from the analytic model by the finite element method.

[Translation done.]

MEANS

[Means for Solving the Problem] In order to attain the above-mentioned purpose, the data generation method which generates calculating numeric data from the analytic model by the finite element method of this invention of claim 1 A joint number is given to the joint for every element while dividing the analytic model of the structure into two or more elements. It is the data generation method which generates calculating numeric data from the analytic model by the finite element method which analyzes the behavior of the whole structure by adding the numeric value showing the physical quantity in each joint number. It is characterized by performing processing which divides said analytic model into an element by dividing into two steps (the 1st step which divides said analytic model coarsely and is used as a rough division element, and the 2nd step which re-divides said rough division element further, and is used as a fragmentation element). This invention of claim 2 is characterized by constituting said analytic model by said two or more rough division element trains by setting up the rough division element train of one train about said two or more rough division elements located in a line with the one direction in the 1st-step division processing of said analytic model in the data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 1. This invention of claim 3 is characterized by setting up the joint number to said each joint as a joint number for rough division trains along the direction where said rough division element is located in a line for said two or more rough division element trains of every in the data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 2.
[0008] In the data generation method which generates calculating numeric data from the analytic model by the finite element method according to claim 3, this invention of claim 4 is characterized by resetting it as the joint number of the order which unified the joint number of said whole analytic model based on said contact numerical order for rough division trains while it unifies each train of said ****** element train and returns it to said whole analytic-model configuration. The data generation equipment which generates calculating numeric data from the analytic model by the finite element method of this invention of claim 5 The input unit which can input various alphabetic characters and numeric values, such as data and a program, The storage which memorizes the program and data which analyze the behavior of the structure with this analytic model while memorizing the analytic model by the finite element method of the structure at least, Count equipment equipped with the processor which generates calculating numeric data by count from said analytic model with the application of said program and said data, The count result of said count equipment A display unit, an airline printer, external storage, It is data generation equipment which generates calculating numeric data from the analytic model by the finite element method equipped with the output unit which can be outputted to a communication device etc. or for said program The contents for performing the data generation method which generates calculating numeric data from the analytic model by the finite element method indicated by any 1 term of claims 1-3 are indicated. With said count equipment It is characterized by generating calculating numeric data from said analytic model with said data generation method. As mentioned above, by setting up that to which the analytic model of the structure was coarsely divided into the rough division element at first, next two or more the rough division elements were located in a line with the one direction with one train Constitute the analytic model of the structure from two or more trains, and said rough division element is

further re-divided into a fragmentation element. While setting a joint number as each joint of each fragmentation element along with the list of said train, unifying said two or more trains finally and considering as the whole analytic model By changing for the joint number which lets the whole analytic model pass about the joint number in each joint of each fragmentation element, it makes it possible to reduce the computational complexity and the amount of memory which are needed for structural analyses, such as the finite element method.

[0009]

[Embodiment of the Invention] Hereafter, it explains based on the operation gestalt illustrating this invention. Drawing 1 is drawing showing an example of the analytic model of the structure. As shown in drawing 1 , this analytic model was made into the two-dimensional analytic model S1 which has a five-cornered configuration. This analytic model S1 is explained below about the case where it divides into the element of a four-side form. As shown in drawing 2 , an analytic model S1 is first divided into the rough division elements RE1-RE5 of a four-side form coarsely. Drawing 3 is drawing showing the case where a rough division train is set up according to the list of the one direction of the rough division element of drawing 2 . The rough division element RE1 and the rough division element RE2 are located in a line with the one direction (the one-dimension-array direction) of right and left among drawing, and set up the rough division train 1 with the rough division element RE1 and the rough division element RE2. Similarly, the rough division element RE3 - the rough division element RE5 are located in a line with the one direction (the one-dimension-array direction) of right and left among drawing, and set up the rough division train 2 with the rough division element RE3 - the rough division element RE5. Drawing 4 is drawing showing the case where each ****** element of the rough division train 1 of drawing 3 and the rough division train 2 is re-divided into a fragmentation element required for analysis. The rough division train 1 of drawing 4 is carried out 2 ****s further up and down, and 2 ****s of each are made right and left also for the rough division element RE1 and the rough division element RE2. Namely, as for the rough division element RE1 and the rough division element RE2, each element with which each rough division element was further quadrisected, and was divided turns into a fragmentation element. The rough division train 1 sets to FE1, FE2, FE3, and FE4 from the left the fragmentation element of the train of the bottom carried out 2 ****s up and down at order. Moreover, the fragmentation element of the train of the top is set to FE5, FE6, FE7, and FE8 from the left at order. A joint number is set up with 1, 2, 3, 4, and 5 sequentially from the left about the joint number of the fragmentation element FE1, FE2, FE3, and FE4 bottom. Moreover, it sets up with 6, 7, 8, 9, and 10 sequentially from the left about the joint number of the fragmentation element FE1, FE2, FE3, and FE4 top and the fragmentation element FE5, FE6, FE7, and FE8 bottom. Furthermore, it sets up with 11, 12, 13, 14, and 15 sequentially from the left about the joint number of the fragmentation element FE5, FE6, FE7, and FE8 top.

[0010] Since it cannot divide into two up and down simply, the rough division train 2 of drawing 4 is first divided into two up and down about the rough division elements RE3 and RE4. Furthermore, it divides into two up and down about the rough division elements RE4 and RE5. Then, the rough division element RE4 will be quadrisected. About the rough division elements RE3 and RE5, it divides into two like the rough division elements RE1 and RE2 at right and left. Thus, by dividing, all the rough division elements RE3-RE of the rough division train 2 are quadrisected, and each divided element turns into a fragmentation element. The rough division train 2 sets to FE9, FE10, FE11, FE12, and FE13 from the left the fragmentation element of the train of the bottom carried out 2 ****s up and down at order. Moreover, the fragmentation element of the train of the top is set to FE14, FE15, FE16, FE17, FE18, FE19, and FE20 from the left at order. A joint number is set up with 1, 2, 3, 4, and 5 sequentially from the left about the joint number of the fragmentation element FE9, FE10, FE11, FE12, and FE13 bottom. Moreover, it sets up with 6, 7, 8, 9, 10, 11, and 12 sequentially from the left about the joint number of the fragmentation element FE9, FE10, FE11, FE12, and FE13 top and the fragmentation element FE14, FE15, FE16, FE17, FE18, FE19, and FE20 bottom. Furthermore, it sets up with 13, 14, 15, 16, 17, 18, 19, 20, and 21 sequentially from the left about the joint number of the fragmentation element FE14, FE15, FE16, FE17, FE18, FE19, and FE20 top. Drawing 5 is drawing showing what (it changed) the rough division train of drawing 4 is unified and the joint number reset up for to the whole analytic model. In drawing 5 , the rough division train 1 and the rough division train 2 are unified, and constitute the analytic model S1.

Although the configuration of the fragmentation elements FE1-FE20 is the same as the configuration of drawing 4 except that the rough division train 1 and the rough division train 2 are joined, the joint number in the rough division train 2 of drawing 4 is reset up. About the joint numbers 1-5 of the rough division train 2 of drawing 4 , since it joins to the joint numbers 11-15 of the rough division train 1, and 1 to 1 by integration with the rough division train 1, the joint numbers 1-5 disappear taking advantage of the joint numbers 11-15. About the joint numbers 6-12 of the rough division train 2 of drawing 4 , since it becomes the next joint number of the joint numbers 11-15 of the rough division train 1 by integration with the rough division train 1, it resets the joint numbers 6-12 with the joint numbers 16-22. About the joint numbers 13-21 of the rough division train 2 of drawing 4 , since it becomes the next joint number of the joint numbers 16-22 of the rough division train 2 by integration with the rough division train 1, it resets the joint numbers 13-21 with the joint numbers 23-31.
[0011] Drawing 6 is the block diagram showing 1 operation gestalt of the data generation equipment which generates calculating numeric data from the analytic model by the finite element method of this invention. In the data generation equipment 1 which generates calculating numeric data from the analytic model by the finite element method of this invention, it is constituted by the output unit 5 which outputs the count result by the storage 4 and the count equipment 3 which memorizes programs, the various set points or various data etc. which generate calculating numeric data, such as a data generation method, etc. from the analytic model by the input devices 2, such as a keyboard and a digitizer, the count equipment 3 which consists of two or more processors, and the finite element method. First, the operator of count equipment 1 inputs beforehand programs, such as a data generation method which generates calculating numeric data from the analytic model by the finite element method, with an input unit 2, and stores them in storage 4. Next, the operator of count equipment 1 inputs the various set points, data, etc. with an input unit 2. Count equipment 3 performs count based on the various set points and data which read the program of the data generation method which generates calculating numeric data from the analytic model by the finite element method from the store 4 with the inputted various set points, and were inputted. A count result is outputted from the output unit 5 of count equipment 1. It is recognized by the operator with a display unit, an airline printer, etc., external storage memorizes, or processing of being outputted to a network by the communication device is carried out to the count result outputted from count equipment 1. As mentioned above, since data can be generated using the data generation method which generates calculating numeric data from the analytic model by the finite element method of this invention in case the structure is analyzed with count equipment, computational complexity and the amount of memory required for count are reducible. In addition, although this operation gestalt showed the case of the train to which the rough division element was located in a line with right and left (longitudinal direction in drawing) about the rough division train, it is not necessary to restrict this invention to this, and when it is the train to which the rough division train was located in a line with the upper and lower sides (lengthwise direction in drawing) that what is necessary is just to have stood in a line on the single dimension, or also when it is the train aslant located in a line, it can apply, and the array does not need to be a straight line strictly.

[Translation done.]

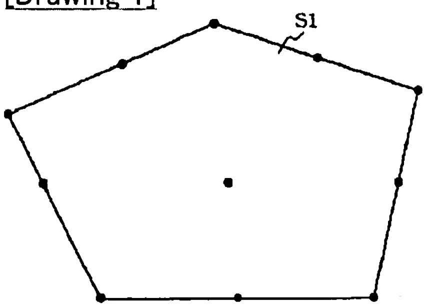
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing an example of the analytic model of the structure of a complicated configuration.
[Drawing 2] It is drawing showing the case where the analytic model of drawing 1 is coarsely divided into a four-side form element.
[Drawing 3] It is drawing showing the case where a rough division train is set up according to the list of the one direction of the rough division element of drawing 2 .
[Drawing 4] It is drawing showing the case where each ****** element of the rough division train 1 of drawing 3 and the rough division train 2 is re-divided into a fragmentation element.
[Drawing 5] It is drawing showing what (it changed) the rough division train of drawing 4 is unified and the joint number reset up for to the whole analytic model.
[Drawing 6] It is the block diagram showing 1 operation gestalt of the data generation equipment which generates calculating numeric data from the analytic model by the finite element method of this invention.
[Drawing 7] It is drawing showing the matrix generally generated by the finite element method.
[Drawing 8] (a), (b), and (c) are drawings showing the example of the matrix of drawing 7 .
[Drawing 9] (a), (b), and (c) are drawings having shown the example of being able to reduce half-band width by changing the joint number of the analytic model of drawing 8 .
[Description of Notations]
1 [... Storage, 5 / ... Output unit] ... Count equipment, 2 ... An input unit, 3 ... An arithmetic unit, 4

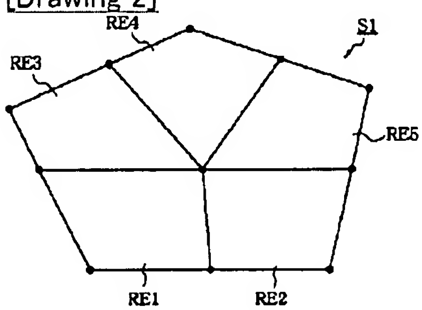
[Translation done.]

DRAWINGS

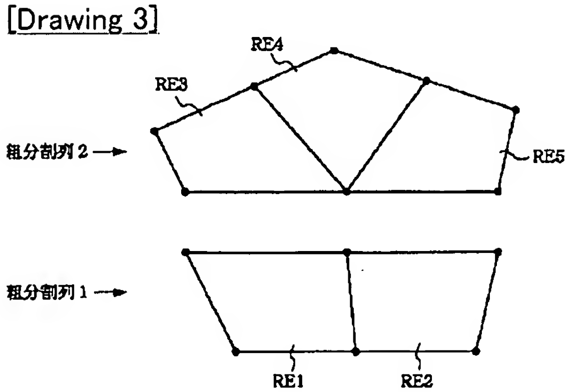
[Drawing 1]



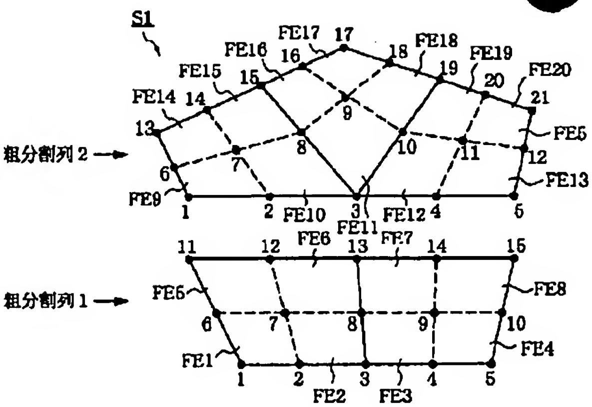
[Drawing 2]



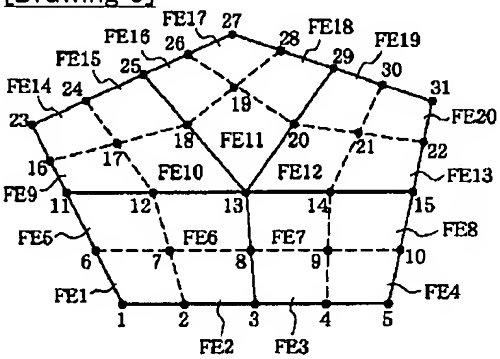
[Drawing 3]



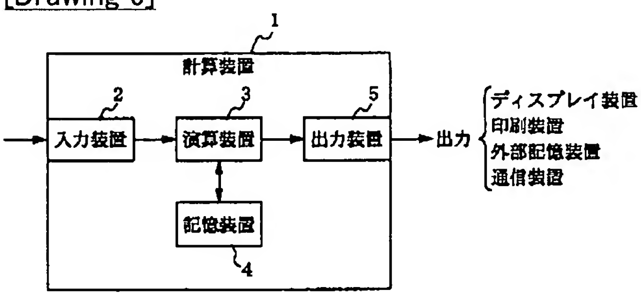
[Drawing 4]



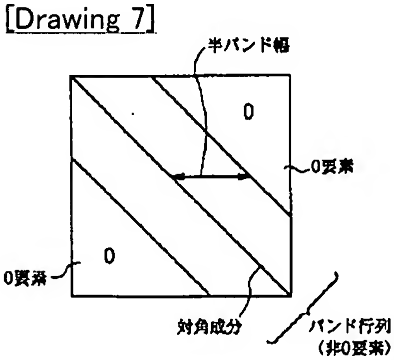
[Drawing 5]



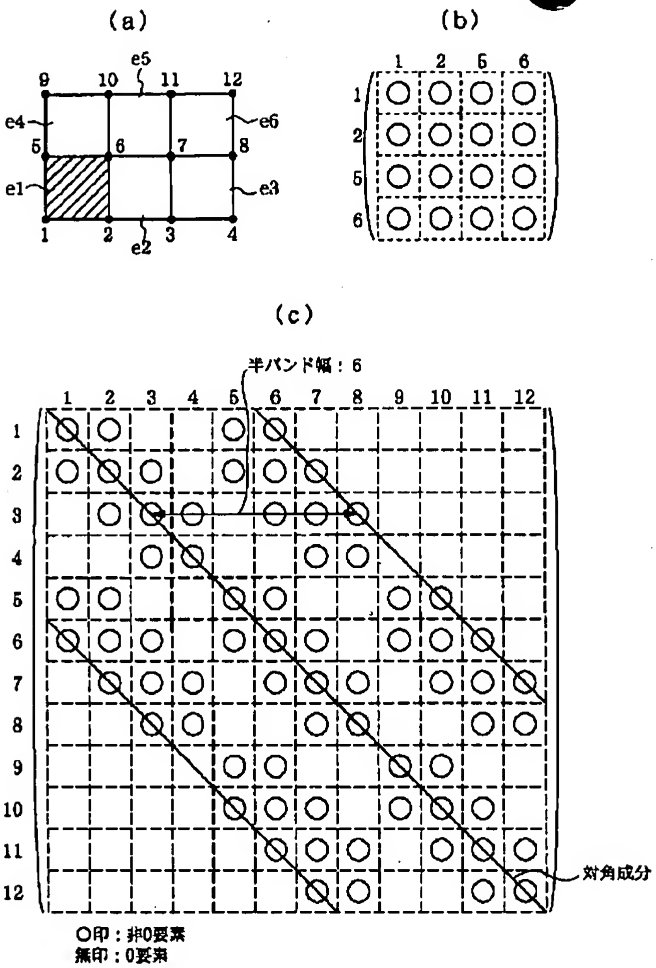
[Drawing 6]



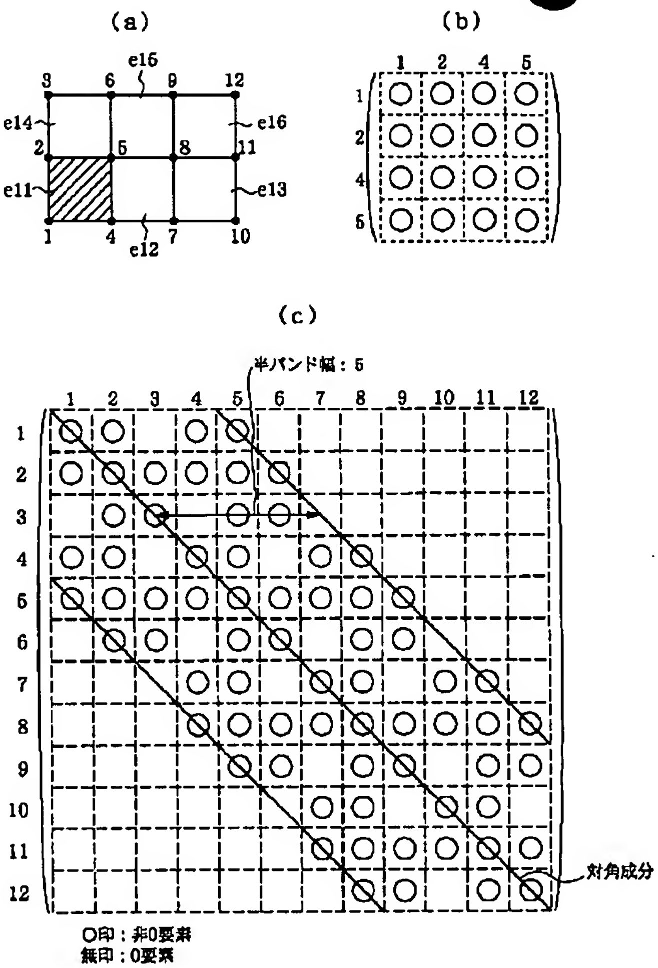
[Drawing 7]



[Drawing 8]



[Drawing 9]



[Translation done.]